Noto User Manual

32-m Antenna

Version 1

Elena Cenacchi, Alessandro Orfei, Francesco Schillirò, Karl-Heinz Mack

e.cenacchi@ira.inaf.it

THE RADIOTELESCOPE

Last update : 11 September 2006

Index

1 – INTRODUCTION 5

2 – ANTENNA STRUCTURE 7
2.1 Primary reflector 7
2.2 Quadrupod and secondary reflector 8
2.3.1 *Wobbling* 9
2.3 Pointing errors 10
2.4 Specification summary 11
2.4.1 *Observation conditions* 11
2.4.2 *Surface accuracy* 11
2.4.3 *Pointing errors* 12

3 – OPTICS 13
3.1 Primary focus 13
3.2 Cassegrain focus 14
3.3 Servosystems specifications 15

4 – FRONT END 17
4.1 Feeds and receivers 17
1.6 GHz 18
2.3/8.3 GHz 19
5 GHz 20
22 GHz 21
43 GHz 22
4.2 Distributions 23
4.3 Control room 24

5 – EFFICIENCY AND SYSTEM TEMPERATURE 25

6 – VLBI 27

7 – OBSERVING MODES 29
7.1 ON-OFF techniques 29
7.2 Mapping techniques 29

8 – BACK END 33
8.1 Spectrometers 34
8.1.1 *Arcos* 34
8.2 Continuum 35
8.2.1 *Mark IV* 35
8.3 VLBI 37
8.3.1 *Mark IV* 37

1. Introduction

The Noto 32 m antenna is a Cassegrain radiotelescope operated since 1989, by the Istituto di Radioastronomia, until 2004 part of the CNR (Consiglio Nazionale delle Ricerche) and now part of the INAF (Istituto Nazionale di AstroFisica).

Fig. 1.1 : The Noto antenna

The main features of this instrument are the following :

- Active surface
- Secondary reflector wobbling (shifting time ≤ 1 sec at v ≥ 20 GHz)
- Complete automation and remote control of the observing settings

Position	Noto, Italy
Coordinates	Lat. 36°52'33.78" N - Long. 14°59'20.51" E Alt. 30 m f.s.l.
Optics	Cassegrain
Frequency coverage	1.4 ÷ 86 GHz
Primary reflector diameter	32 m
Secondary reflector diameter	3.2 m
Available foci	Primary f/D = 0.32 Cassegrain f/D = 3.04
Elevation range	0°÷90°
Azimut range	± 270°
Slew rates (wind speed < 60 km/h)	48°/min Azimuth 30°/min Elevation
Surface accuracy (*rms* specified)	0.1 mm
Pointing accuracy (*rms* specified)	8 arcsec
FWHM Beamwidth	38.7 arcmin/f (GHz)
Gain	0.10 ÷ 0.16 K/Jy
First secondary lobes	circa 20 dB under the main lobe
Receivers mounts	Primary Focus : movable positioner (2 receiver bays) Cassegrain Focus : fixed (1 receiver bay)
Parabolic reflector correction system	Active surface (Look-up table)

Tab. 1.1 : Characteristics of the Noto antenna

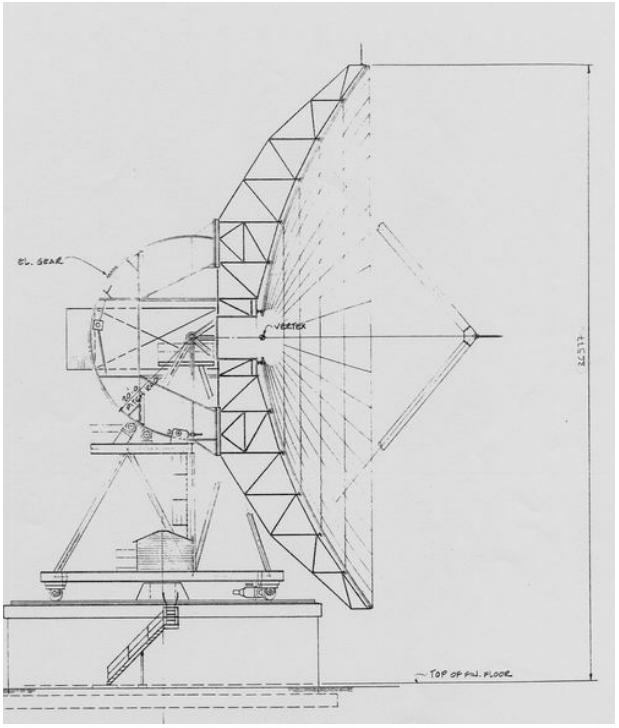


Fig. 1.2 : The Noto antenna, side

2. Antenna Structure

2.1 Primary Reflector

The primary reflector. diameter 32 m, is made of 240 aluminium panels (RMS = 0.4 mm) substained by a backup reticular truss. The housing of the Cassegrain focus feeds is at the mirror vertex.

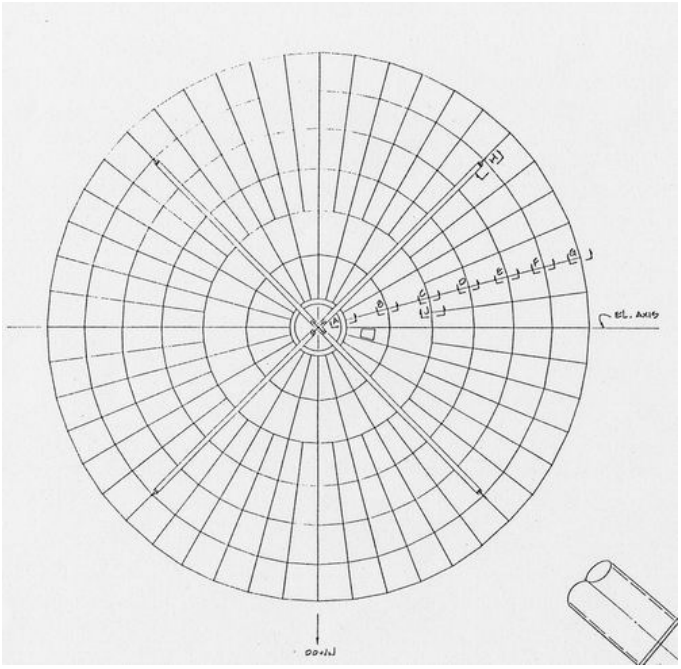
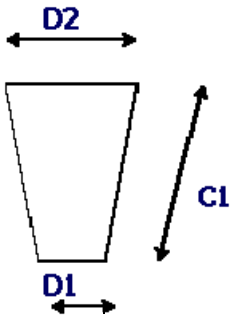


Fig. 2.3 : Primary reflector, front



	C1 (mm)	D1 (mm)	D2 (mm)
Raw B	2617.8	437.62	1113.96
Raw C	2604.15	1113.96	1770.4
Raw D	2617.24	887.1	1206.06
Raw E	2648.38	1206	1515
Raw F	2659.33	1515.04	1810.74
Raw G	2718	1810.74	2098.14

Tab 2.1 : Geometry of the panels

2.2 Quadrupod and Secondary Reflector

The primary reflector backup structure substains the secondary mirror, placed at a distance of 9 m, through 4x45° inclined beams (quadrupod).

The secondary mirror is a hyperbolic reflector, 3.2 m diameter, made of a single aluminium panel (rms = 0.35 mm). On the backup structure 3 mechanical actuators are installed and allow the mirror to tilt around the 3 axes. In addition the whole system can translate along the x and y axis.

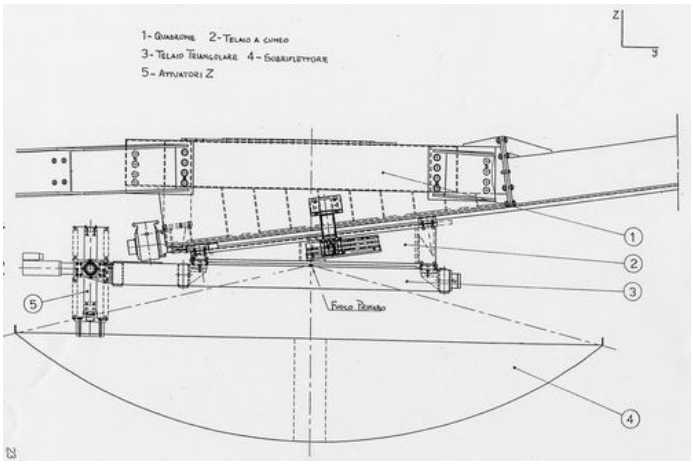


Fig. 2.4 : Hyperbolic mirror

The mirror must completely be retracted along the y axis when the primary focus is used.

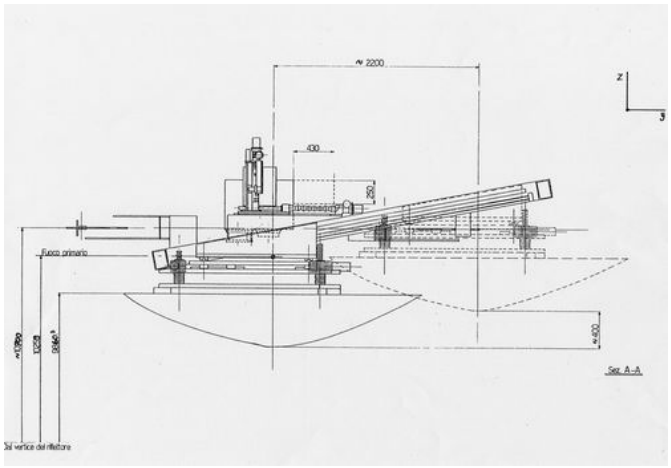


Fig. 2.5 : Configuration for Cassegrain focus usage (plain line) and primary focus usage (dotted line)

The mirror and the quadrupod induce an obstruction on the primary reflector of nearly 4%.

Cause	Obstruction
Sub-reflector	2 %
Quadrupod	2 %
Total	4 %

Tab. 2.2 : Primary reflector obstruction

2.2.1 Wobbling

The system that rotates the secondary mirror has been optimized in order to enhance the number of receivers that can be installed at the Cassegrain focus , but actually it is used only to realize the "Wobbling" technique, using one receiver at once. Typical shifting times, shorter then those used in Position Switching, are listed in the following table.

Frequency (GHz)	Beam HPBW (")	Mirror rotation 2.5 beam (°)	Required time (sec)	Mirror rotation 5 beam (°)	Required time (sec)
5	450	2.56	1.16	5.12	2.12
6	390	2.22	1.03	4.44	1.86
22	120	0.68	0.45	1.37	0.71

Tab. 2.3 : Wobbling time for 2.5-beam and 5-beam throws

2.3 Pointing Errors

The accuracy of the pointing correction increases with the observing frequency, i.e. as the antenna beam width decreases.
Commonly the following is assumed :

$$\delta_p = \frac{HPBW}{10}$$

δ_p = pointing accuracy

HPBW = -3 dB beam width (main lobe)

For the Noto antenna the values are listed in the following :

Frequency (GHz)	HPBW (')	Error (')
1.5	29	≤ 2.9
22	2	≤ 0.2

Tab. 2.4 : Beam and pointing errors

The systematic errors are usually quite high (some arcminute). Anyway they have been determined according to the antenna position (Az/El) after apposite astronomical observations (reference radio sources), and a correction model has been derived.
Once the model has been applied, the residual error is 0.1' (both in azimuth and elevation), exactly as required.

2.4 Specification Summary

2.4.1 Observation conditions

	Parameters	Specifications
Precision	Wind, continuous Wind, gusts	< 25 km/h 20÷ 30 km/h
	Sun	Absent
	Precipitation	Absent
	Temperature	-25 ÷ 30 °C
	Humidity	< 90 %
Normal	Wind, continuous Wind, gusts	< 65 km/h 50 ÷ 80 km/h
	Precipitation	Absent
	Temperature	-30 ÷ 50 °C
	Humidity	< 100%
Survival	Wind	200 km/h
	Precipitation	< 5 cm/h snow
	Seismic	0.3 g horizontal

Tab. 2.5 : Observation conditions

In survival conditions, and when not in use, the antenna must be settled at 90° elevation and 206.151° azimuth (stow position).

2.4.2 Surface Accuracy

Structural Elements	(RSS mm) 90° El	(RSS mm) 60° El
Primary reflector panels	0.1	0.1
Secondary reflector panels	0.38	0.38
Gravitational deformation	0	0
Total surface accuracy	0.2	0.2

Tab. 2.6 : Surface accuracy at 90° and 60° elevation

To estimate the phase error ε from the surface accuracy, the following can be used :

$$\varepsilon = \frac{4\pi\delta}{\lambda} \text{ [rad]}$$

δ = surface accuracy
λ = observation wavelength

Usually a maximum tolerable phase error is assumed as $\varepsilon \approx 36° \approx 0.63$ rad , so that the minimum observable wavelength is

$$\lambda_{\min} \approx 20\delta_{\max}$$

This means for the Noto antenna :

$$\lambda_{\min} \approx 4\,\text{mm} \rightarrow \nu_{\max} \approx 75\,\text{GHz}$$

2.4.3 Pointing accuracy

Observation condition	Pointing accuracy (rms arcmin)
Normal/Precision	0.13

Tab. 2.7 : Pointing accuracy

3. Optics

The Noto antenna has 2 focal positions :

- Primary focus : F1
- Cassegrain focus : F2

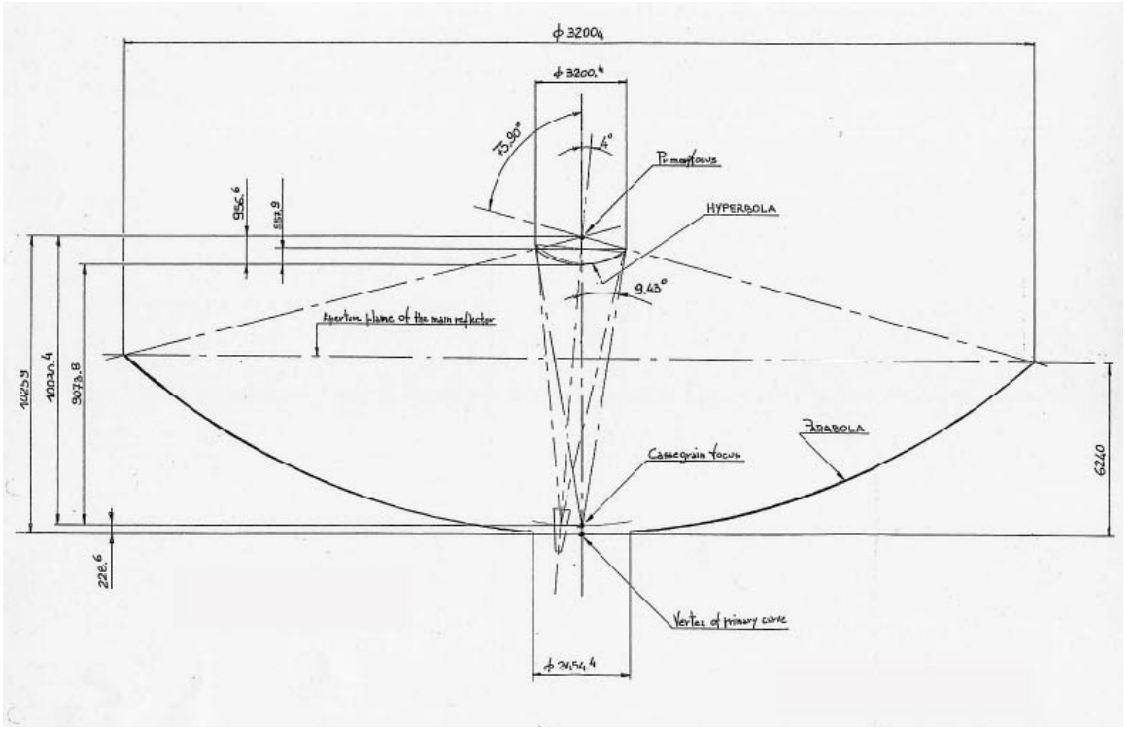


Fig. 3.1 : Optics of Noto antenna [dimensions : mm]

3.1 Primary Focus

With the Cassegrain optics the primary reflector focus is usable only if the secondary reflector is completely retracted. Behind the mirror a movable positioner is installed, equipped with 3 receiver bays.

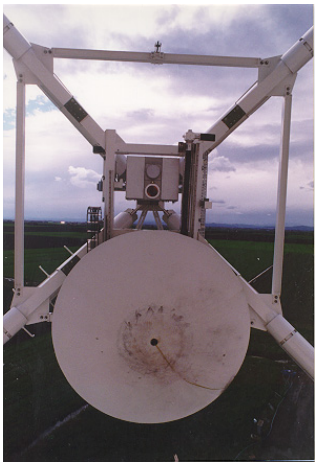


Fig. 3.2 : Primary focus feed positioner

The primary mirrror focal length is nearly 10.3 m, therefore the focal ratio is $F_1/D \approx 0.32$.

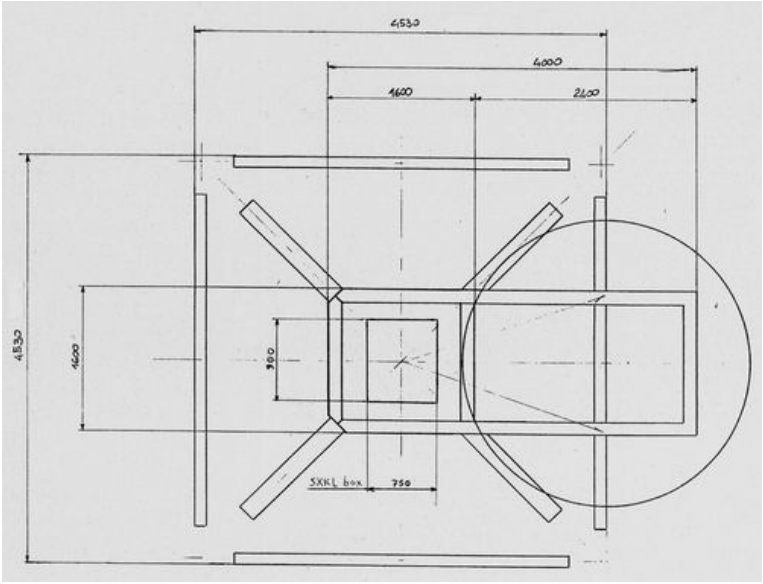


Fig. 3.3 : Primary focus (dimensions : mm)

3.2 Cassegrain Focus

The secondary mirror (9 m from the primary mirror) allows the usage of the Cassegrain focus (at nearly 20 cm above the reflector vertex)

This focus has been designed to offer several adjacent focal positions, which can be obtained through the angular movement of the secondary mirror (see fig. 3.4).

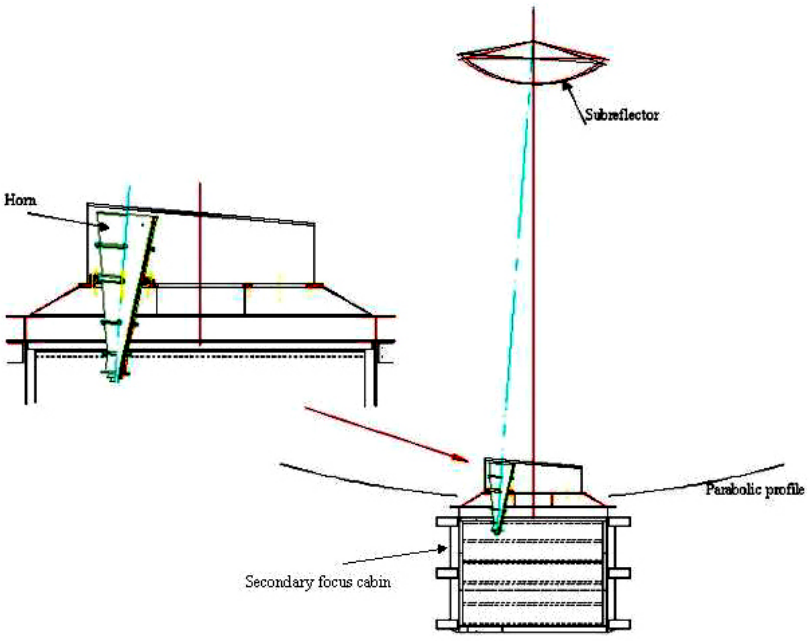


Fig. 3.4 : Cassegrain focal plane

Unlike the Medicina antenna, the focal positions do not host different receivers and the frequency change requires the installation of the necessary receiver into the central bay. The

Wobbling technique is used only to realize the Beam Switching (e.g. On Source-Off Source) and to carry faster radiometric measurements.

The secondary hyperbolic reflector yelds a magnification i_2 which depends on the ratio between the focal length and the distance from the prime focus (nearly 9 m and 1 m, respectively).

The total focal length can be estimated as follows :

$$i_2 = \frac{9.074}{0.956} \approx 9.49$$
$$F_2 = i_2 \cdot F_1 \approx 97.36 \,[\mathrm{m}]$$

The focal ratio is therefore: $F_2 / D \approx 3.04$

3.3 Servosystems Specifications

Azimuth drive		Unity	Value
Kinematics	Angular travel	(°)	540
	Angular velocity	(°/sec)	0.8
	Angular acceleration	(°/sec^2)	0.82
Configuration	Number of wheels	(-)	4
	Driving wheels	(-)	2
	Drives per wheel	(-)	1
Track	Diameter	(m)	18.3

Tab. 3.1 : Azimuth drive

Elevation drive		Unity	Value
Kinematics	Angular travel	(°)	90
	Angular velocity	(°/sec)	0.5
	Angular acceleration	(°/sec^2)	0.31

Tab. 3.2 : Elevation Drive

Primary focus feed positioner		Unity	Value
Kinematics	Linear travel	(mm)	420
	Linear velocity	(mm/sec)	7.2
	Linear acceleration	(mm/sec^2)	24

Tab. 3.3 : Primary focus feed positioner, transverse axis

Primary focus feed positioner z axis		Unity	Value
Kinematics	Linear travel	(mm)	350
	Linear velocity	(mm/sec)	7.2
	Linear acceleration	(mm/sec^2)	24

Tab. 3.4 : Primary focus feed positioner, z axis

Sub-reflector		Unity	Value
Kinematics	Linear travel x axis	(mm)	160
	Linear travel y axis	(mm)	160
	Linear travel y axis out of focus	(mm)	2240
	Linear travel z axis	(mm)	250
	Angular travel x axis	(°)	±4.2*
	Angular travel y axis	(°)	±4.2*
	Linear velocity x axis	(mm/sec)	55.5
	Linear velocity y axis	(mm/sec)	17.1
	Linear velocity z axis	(mm/sec)	48.3
	Angular velocity	(°/sec)	1.9

Tab. 3.5 : Sub-reflector kinematics

4. Front End

4.1 Feeds and Receivers

The Noto antenna covers the range 1.35÷48 GHz.

The following receivers are available :

Band (Label)	ν_0 (GHz)	λ (cm)	Channels	ν_{Lsky} (GHz)	ν_{Hsky} (GHz)	Gain K/Jy	Noise Temperature (K)	Bandwidth (MHz)	HPBW	Hemt	Cooled
P	0.327	92	L+R	0.317	0.332	0.1	150	-	100′	N	N
UHF	0.5-1	60-30	L+R	0.5	1	0.1	-	-	32′-64′	N	N
L	1.6	18/21	L+R	1.40	1.72	0.12	120	2x35	22′	Y	N
S	2.3	13	R	2.2	2.36	0.17	120	2x160	20′	Y	N
C	5	6	L+R	4.7	5.05	0.15	30	2x350	8′	Y	Y
X	8.3	3.6	R	8.18	8.58	0.15	110	2x400	4.8′	Y	N
12	12	2.5	HV	11.70	12.75	-	-	-	3′	N	N
K	22	1.3	L+R	22.18	22.46	0.13	90	2x400	1.7′	Y	Y
Q	43	0.7	L+R	38	48	0.1	70	2x400	0.9′	Y	Y

Tab. 4.2 : Receivers parameters

Primary Focus
Cassegrain Focus

$\nu_{Lsky} \div \nu_{Hsky}$: receiver maximum bandwidth

The receiver labels have been assigned only for identification purpose.

At UHF, P, L, S bands the effective bandwidths can be smaller due to RFI.

1.6 GHz

Type	Hot
Channels	2
Polarization	LHC-RHC
Central frequency (GHz)	1.56
Noise temperature (K)	120
Useful RF band (GHz)	1.40÷1.72
RF filter width (MHz)	320
IF filter width (MHz)	35
Instantaneous RF band (GHz)	1.366÷1.446
LO frequency (GHz)	1.279
LO range (GHz)	1.020÷1.305
Conversion (GHz)	Single USB 0.330÷0.365

Standard parameters of the 1.5 GHz parameters

The maximum bandwidth is 80 MHz, tunable only within the two RF ranges listed in the above table. To shift the IF standard band inside the RF band of $\Delta\nu$, the LO frequency must be changed (within the range listed in the table) according to the following :

$$RF = 1.4 \div 1.72 \rightarrow \nu_{OL} = 1.279 \pm \Delta\nu$$

2.3-8.3 GHz

Type	Hot Coaxial	
Channels	2	
Polarization	LHC-RHC	LHC-RHC
Central frequency (GHz)	2.28	8.58
Noise temperature	120	110
Useful RF band (GHz)	2.20÷2.36	8.18÷8.58
RF filter width (MHz)	160	400
IF filter width (MHz)	160	400
Instantaneous RF band (GHz)	2.20÷2.36	8.18÷8.58
LO frequency (GHz)	2.020	8.080
LO range (GHz)	0	0
Conversion (GHz)	Single USB 0.18÷0.34	Single USB 0.1÷0.5

Standard parameters of the 2.3-8.3 GHz coaxial receiver

It is possible to use the receivers both together (coaxial, 2 IF outputs, one per each frequency) and separately (2 IF outputs). For the VLBI coaxial observation one channel only for each receiver is used, typically the right hand circular polarized one (this because the Mark IV can handle only 2 IF inputs).

5 GHz

Type	Cooled
Channels	2
Polarization	LHC-RHC
Central frequency (GHz)	4.875
Noise temperature	30
Useful RF band (GHz)	4.65÷5.15
RF filter width (MHz)	500
IF filter width (MHz)	350
Instantaneous RF band (GHz)	4.700÷5.050
LO frequency (GHz)	1.150x4
LO range (GHz)	1.138÷1.175
Conversion (GHz)	Single USB 0.1÷0.45

Standard parameters of the 5 GHz receiver

To shift the IF standard band inside the RF band of $\Delta\nu$, the LO frequency must be changed (within the range listed in the table) according to the following :

$$\nu_{OL} = \frac{4.600 \pm \Delta\nu}{4}$$

22 GHz

Type	Cooled
Channels	2
Polarization	LHC-RHC
Central frequency (GHz)	22.150
Noise temperature (K)	90
Useful RF band (GHz)	21.90÷22.40
RF filter width (MHz)	500
IF filter width (MHz)	400
Instantaneous RF band (GHz)	21.95÷22.35
LO1 frequency (GHz)	1.150 x18
LO2 frequency (GHz)	1.150
LO1 range (GHz)	20.668÷20.778
Conversion (GHz)	Double USB 1.147÷1.153 0.1÷0.5

Standard parameters of the 22 GHz receiver

To shift the IF standard band inside the RF band of $\Delta\nu$, the LO frequency must be changed (within the range listed in the table) according to the following :

$$\nu_{OL} = \frac{22.15 \pm \Delta\nu - 0.3}{19}$$

43 GHz

Type	Cooled
Channels	2
Polarization	LHC-RHC
Central frequency (GHz)	42.5
Noise temperature (K)	40
Useful RF band (GHz)	37÷48
RF filter width (MHz)	11000
IF filter width (MHz)	400
Instantaneous RF band (GHz)	42.3÷42.7
LO1 frequency (GHz)	15.86
LO1 range (GHz)	13.21÷18.51
LO2 frequency (GHz)	10.500
Conversion	Double USB 10.5÷11.5 0.1÷0.5

Standard parameters of the 43 GHz receiver

To shift the IF standard band inside the RF band of $\Delta\nu$, the LO frequency must be changed (within the range listed in the table) according to the following :

$$\nu_{OL} = \frac{42.5 \pm \Delta\nu - 10.5 - 0.271}{2}$$

4.2 Distribution

The connections between the radiotelescope foci involve three different kinds of signal :

. Local Oscillator : in order to cut down the expenses related to the construction of a high number of independent superheterodyne receivers, a common solution is to share some local oscillators (at least for one conversion). A single local oscillator therefore can serve more receivers through a signal distribution system.

. IF : the RF signals, once received and converted by the Front End, are sent to the Back End installed in the Control Room, at the antenna base.

. Reference : 5-MHz H-maser signal, necessary for the local oscillator stability.

All the signals are distributed via coaxial cable.

The distribution scheme is simplified by the fact that there are only two double-conversion receivers (6 GHz at the Cassegrain focus and 22 GHz at the primary focus). Both use the same local oscillator for the second conversion. Besides the two receiver channels cannot be tuned at different positions inside the RF bandwidth.

The LO signal is distributed by an LO distributor (OLD).

The reference distributor (REFD) and the IF distributor (IFD) are also installed in the Cassegrain focus. The receiver can be chosen from the Control Room using the selector.

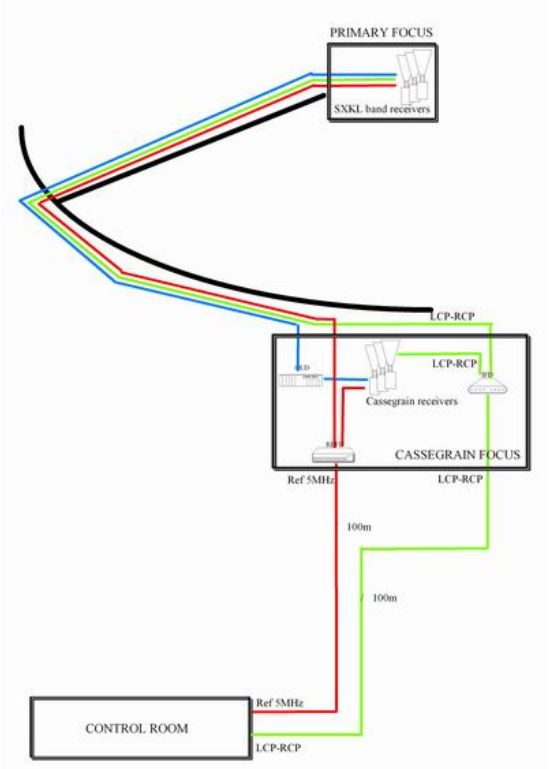


Fig. 4.2 : Signal distribution between the foci

4.3 Control Room

The backend systems are installed in the control room, located at the antenna's base. It is connected to the foci through the links shown in the following (red line and green line are fiber optic links) :

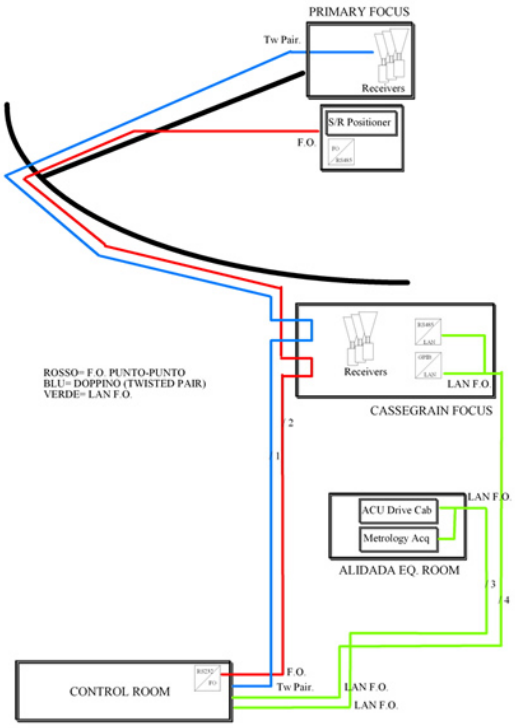


Fig. 4.3 : Control links

From the control room receivers, antenna and sub-reflector movement can be controlled. Moreover the new metrology system (temperature sensors) and a little antenna used for the olographic measurement of the surface can be operated.

5. Efficiency and System Temperature

The antenna gain is defined as :

$$G = 10^{-26} \frac{m \eta_A A_g}{k_B} \quad \left[\frac{\mathrm{K}}{\mathrm{Jy}}\right]$$

m = 0.5 (non polarized radiation)
A_g = geometric area
k_B = Boltzmann's constant
η_A = antenna efficiency

For the Noto antenna, the constants are :

$$10^{-26} \frac{A_g}{2 \cdot k_B} \approx 0.292$$

η_A is the overall efficiency, estimated assembling all the signal degradation factors.

The antenna gain varies according to the elevation and it reaches a maximum at 45°. A good interpolation is obtained with a second degree polynomial, such as :

$$ax^2 + bx + c$$

The coefficients of the normalized polynomials, at each frequency, are listed in the following :

Frequency (GHz)	*a*	*b*	*c*
0.327	0	0	1
0.5-1	0	0	1
1.6	$-6.8310687 \cdot 10^{-5}$	$7.285044 \cdot 10^{-3}$	$8.0577027 \cdot 10^{-1}$
2.3	$-5.8197959 \cdot 10^{-5}$	$9.4270958 \cdot 10^{-3}$	$6.1824204 \cdot 10^{-1}$
5	$-1.4396956 \cdot 10^{-5}$	$1.9594323 \cdot 10^{-3}$	$9.3333009 \cdot 10^{-1}$
8.3	$-6.2013643 \cdot 10^{-5}$	$6.9932510 \cdot 10^{-3}$	$8.0284355 \cdot 10^{-1}$
12	$-1.1407653 \cdot 10^{-4}$	$1.1413276 \cdot 10^{-2}$	$7.1452747 \cdot 10^{-1}$
22	$-2.0746800 \cdot 10^{-5}$	$1.7584500 \cdot 10^{-3}$	$2.0928100 \cdot 10^{-2}$

Tab. 5.1 : Normalized gain curves, coefficients

The sensitivity can be estimated as follows :

$$\Delta S = \frac{\alpha T_{sys}}{G\sqrt{\Delta\nu\ \tau\ nN_{IF}}}$$

α = receiver constant (=1)
T_{sys} = system temperature
G = gain (K/Jy)
$\Delta\nu$ = bandwidth
τ = integration time
n = integration number
N_{IF} = available channels (= 1,2)

In the following table the system temperatures and the sensitivities of the Medicina antenna are listed :

ν_0 (GHz)	T receive (K)	Tsys (K)	η_A (%)	G (K/Jy)	SEFD (Jy)	Bandwidth (MHz)	ΔS (mJy$\sqrt{s}$)
0.327	150	170	34	0.1	1700	2x15*	310
0.5-1	-	-	34	0.1	-	-	-
1.6	120	130	41	0.12	1083	2x35*	129
2.3	120	140	58	0.17	823	2x160*	46
5	30	48	51	0.15	320	2x350	12
8.3	110	130	51	0.15	867	2x400	31
12	-	-	-	-	-	2x1050	-
22	90	110	44	0.13	846	2x400	30
43	70	80	28	0.1	800	2x400	21

Tab. 5.2 : Sensitivity of the antenna, assuming τ = 1 sec, n=1, N_{IF} = 2

Primary Focus
Cassegrain Focus

*Usually at these frequencies a narrower bandwidth is used because of RFI.

6. VLBI

Regarding the VLBI observations, the Noto antenna is part of the EVN (European VLBI Network) since 1984.

Some observations have been conducted using only the two Italian antennas (Noto and Medicina) and the Bonn correlator.

7. Observing Modes

7.1 ON-OFF Techniques

In order to reduce as much as possible the atmospheric contribution during an observation, it is possible to apply some techniques based on at least a couple of exposures, one on source and one on an adjacent area ("OFF source" reference position), sufficiently free from emission.

At high frequencies short-scale and strong atmospheric fluctuations affect the observation, hence the need of quick antenna shifts between the two positions (which have to be reasonably close to each other) or the usage of other techniques which do not involve the movement of the entire structure.

The Noto antenna offers the following ON-OFF techniques :

. Position Switching

The antenna shifts between two different positions. The time needed to cover some beams is nearly 5 seconds at all frequencies.

. Wobbling

The shifting of the beam is obtained moving the secondary mirror only. This technique requires always a shorter time than the Position Switching.

In both cases the algorithm used is of the type ON-OFF-ON-OFF.

7.2 Mapping Techniques

If the radio emission is extended over an area larger than the antenna beam, several pointings might be necessary in order to cover the entire area of interest.

The Nyquist theorem states that the correct source sampling along a direction requires an angular distance between the pointings of :

$$\Delta\vartheta = \frac{1\lambda}{2D}$$

The Nyquist sampling is commonly expressed as fraction of the beam :

$$\Delta\vartheta = \frac{1\lambda}{2D} \approx 0.43 HPBW$$

The Noto antenna mainly offers two mapping techniques :

. Raster Scan

The map is obtained through discrete adjacent pointings ("point and shoot" mode). At every step the antenna stops and acquires data for the exposure time required.

The time necessary to cover an area *A,* considering the on-source time only, with a monofeed system, can be roughly estimated as :

$$t_{ON} \approx N_p \cdot t_{esp}$$
$$N_p = \frac{A}{\left(HPBW/2\right)^2}$$

N_p = number of pointings
t_{esp} = single exposure time (depending on the sensitivity required).

The Nyquist sampling is approximated with a half-beam shift in both directions (vertical and horizontal).

Usually this mapping technique is associated with an ON-OFF technique, therefore the total time necessary to complete a survey is given by :

$$t_{TOT} = t_{ON} + t_{OFF} + t_{sh}$$
$$t_{OFF} = N_P \cdot t_{esp} = t_{ON}$$

t_{sh} = antenna shifting time (Position Swiching) or secondary mirror shifting time (Wobbling)

The scan can be conducted in several user-defined ways, the most common is along two perpendicular directions ("cross scan").

. On-The-Fly

In the "On-The-Fly" mode the antenna is moved along one direction, usually with a "raws-and-columns" path, at constant speed. The data are continously acquired and downloaded by the backend every few seconds ("OTF dumps"), corresponding to angular excursions of few arcseconds (depending on the antenna speed).

To reach the required sensitivity it is necessary to scan the same area several times, preferably along different directions.

The ON-source time is :

$$t_{ON} = N_d \cdot t_d$$

t_d = acquisition time
N_d = number of dumps (depending on the required sensitivity).

The Nyquist sampling is obtained if the acquisition time, for each dump, corresponds to an angular antenna shift equal or shorter than the ideal Nyquist distance.

Also the distance between raws and columns must be coherent with the Nyquist sampling.

The On-The-Fly technique is characterized by very short scanning times, so it is the best one in order to reduce the atmospheric contribution (anyway it is necessary to use an ON-OFF technique). For a squared spectroscopic map the total observing time can be estimated with the following :

$$t_{ON} = t_{ON} + t_{OFF}$$
$$t_{OFF} = \sqrt{N_d} \cdot t_{ON}$$

The Noto antenna offers the On-The-Fly Mapping on a user-defined RA/Dec map, with a maximum scan speed of 200 "/s.

8. Back End

The Noto antenna is equipped with the following processing systems :

- ARCOS Autocorrelator

Input	2
Maximum bandwidth per input	16 MHz
Minimum bandwidth per input	0.125 MHz*
Channels	2048
A/D Conversion	2 bit
Available software	ADLB4

Tab. 8.1

*Can be further reduced on request

- Total Power

Input	3
Maximum bandwidth per input	400 MHz
A/D Conversion	16 bit
Available software	ON-OFF

Tab. 8.2

- VLBI (Mark IV / Mark V)

Input	2
Maximum bandwidth per input	400 MHz
Output	28 x 0.125 ÷ 16 MHz
A/D Conversion	1 ÷ 2 bit
Data transfer	1 Gbit/s
Hard Disk	2 x 8 x 400 Gbyte

Tab. 8.3

At 1.4, 1.6, 2.3 GHz the effective bandwidths may be smaller because of RFI.

8.1 Spectrometers

8.1.1 Arcos

Arcos (ARcetri COrrelation Spectrometer) is a digital spectrometer developed by the Osservatorio di Arcetri. It is connected to the Mark IV and receives 2x16-MHz input from the videoconverters of the terminal.

The system could handle 2x20-MHz bands, anyway the Mark IV imposes 2x0.125 ÷ 16 MHz bands (2^n steps)*

The main constituents are :

. 2 correlation boards (2048 channels in total)
. 2 A/D sampler (4 channel sampler boards, 2 bit, 4 levels)

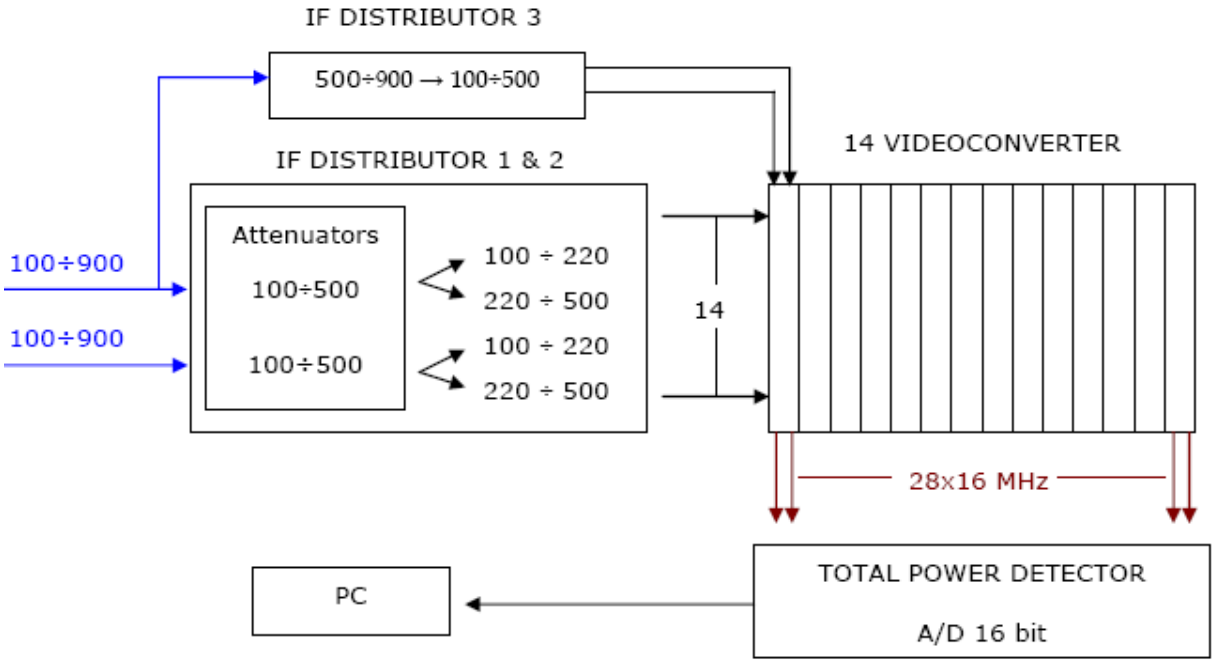


Fig. 8.1 : ARCOS correlator scheme, example at 22 GHz (bands in MHz)

* 0.125 MHz and 1 MHz band are available only with external filters, please ask if available at the site.

8.2 Continuum

8.2.1 Mark IV

The Total Power observations use the Mark IV terminal and the "Field System" software.

The terminal is made of two parts: IF distributor (receives the input from the Front End and splits them in sub-bands), Videoconverters (14 units that operate the base-band conversion and the integration). It is possible to choose between two outputs :

A) 28 narrow bands : minimum width 0.125 MHz, maximum 16 MHz*, central frequency user-defined (maximum total bandwidth 400 MHz).

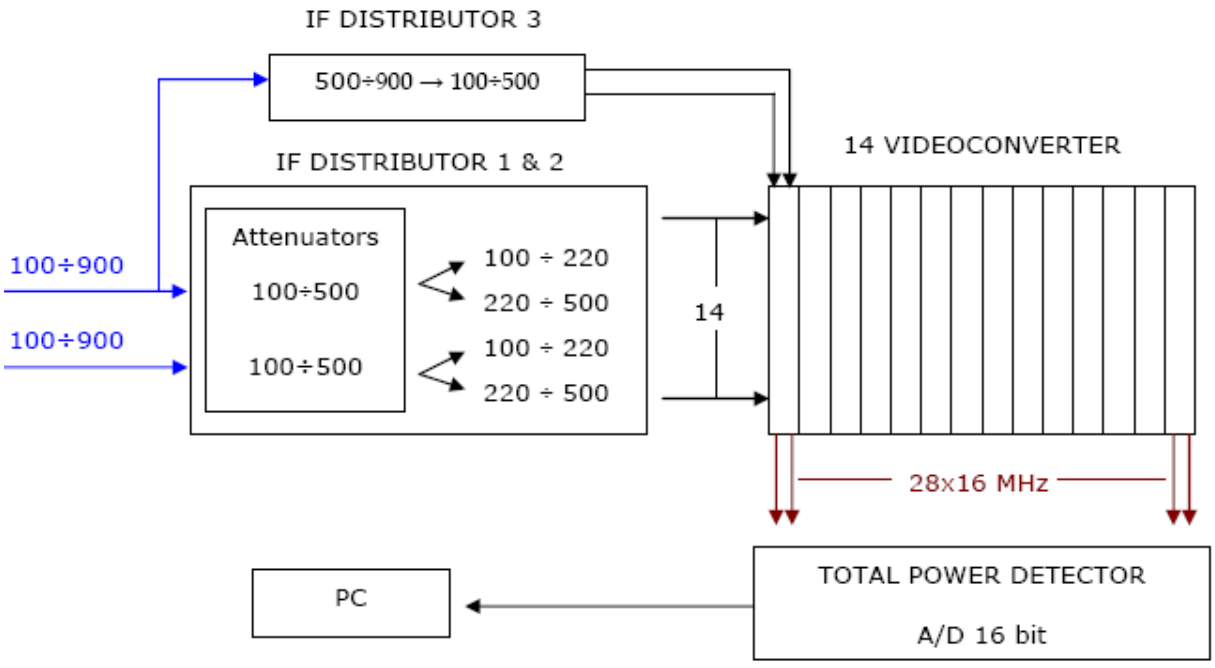


Fig. 8.2 : Maximum bandwidths (MHz) processed by the Mark IV, example at 22 GHz

* 0.125 MHz and 1 MHz band are available only with external filters, please ask if available at the site.

B) Processing of the whole input: 2x400 MHz centered at 300 MHz and 1x400 MHz centered at 700 MHz

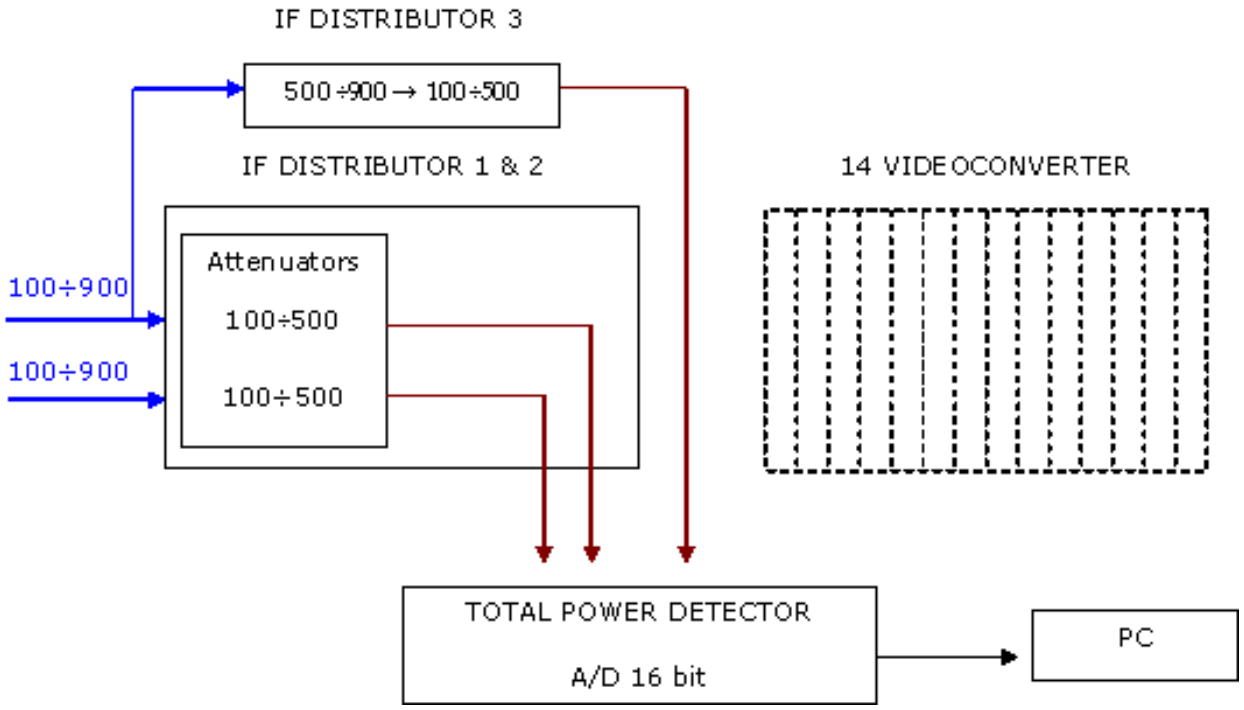


Fig. 8.3 : Maximum total bandwidths (MHz), example at 22 GHz

At 1.4, 1.6, 2.3 GHz effective bandwidths may be considered smaller because of RFI.

8.3 VLBI

8.3.1 Mark V

The VLBI observations are handled with the Mark IV (base conversion, bands splitting, A/D conversion) and the Mark V (data storage) terminals.

The Mark V is made of 2 blocks of 8x400 Gbyte hard disks.